AN ESSAY

ON

THE LAW OF MUSCULAR ACTION.

BY LOUIS MACKALL, M. D.

Second Edition, Corrected and Enlarged.

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PREFACE.

The subject of muscular action is one of the first magnitude in the Science of Physiology, and as such has been laboriously investigated fcr many years past by the Scientists of Europe. It is at this time exciting among them more than usual interest.

Since the discovery of electricity—from observing the effect of this agent on the muscles of recently killed animals—the impression has very generally prevailed that this difficult subject was destined to be fully elucidated by means of electrical experiments. Accordingly, all the investigations referred to above have been directed to this end.

The anticipations resulting from this general impression have not been realized; nor is this suprising, when it is considered that it has been attempted to establish, or to reason out a law of nature that belongs to one department of science, by making use of instances or phenomena which belong to another and very distinct department.

For the last thirty-odd years I have been engaged in investigating this subject of muscular action, but have reasoned solely from instances derived from vital phenomena, or such as are observable in the living body. The following is a succinct account of my proceedings in this investigation:

From often observing, in the practice of medicine, the inadequacy of remedial means made use of, and from frequently experiencing disappointment in my anticipation of the results of the operation of such means, I became convinced that there was something wrong—some great error in the theory, or in the principles of medicine in which I had been taught.

This conviction was brought forcibly home to my mind by the death of my wife from uterine hemorrhage, notwithstanding the use of all the remedial means known to myself and a very skilful medical friend who was present.

Under the influence of grief consequent on this bereavement, I resolved that I would devote the residue of my life to the task of endeavoring to discover, if possible, the error in the theory of medicine that I had before suspected, and in which suspicion I was confirmed by my late experience.

While studying this theory in the books for the above purpose, a case of whitlow (*paronychia*) was presented for treatment. Prompted by the resolve mentioned, I carefully noted the prominent facts of the case. I particularly noticed the pulsation of the arteries at the diseased point and at the wrist; and my attention was forcibly arrested by observing the remarkable difference in that pulsation at the two points. That in the finger was full and strong, while the pulsation of the artery at the wrist was comparatively calm.

Reflecting on the above fact, I arrived at the conclusion that there must be some agency in the arteries of the finger, that were throbbing so violently, to produce this result, that was independent of that in the general circulation; and, in casting about in my mind for some suggestion as to what that agency could be, it occurred to me that the throbbing or distension of the arteries was occasioned by the *action* of their muscular fibres. The correctness of this explanation of the phenomenon in question, was confirmed by running over in

my mind, as I did at the moment, a number of instances wherein irritation was attended with the distension or dilatation of the tubes or hollow organs, when such organs were supplied with muscular fibres—as in the esophagus, in the stomach, intestines, in the uterus in pregnancy, &c.

I had now arrived at a definite proposition; and in the year 1834, in November, I wrote down that proposition in the following words: "All the tubes of the animal body, which are supplied with muscular fibres, have their calibres increased by the *action* of those fibres." This was shown and explained to four medical gentlemen at the time mentioned, and signed by them, witnessing that it was so shown. Three of these gentlemen, namely: Drs. J. H. Skinner, B. B. Hodges, and William Ghiselin are now (1865) living. One of them, the late Dr. Henry Brooke, died a few years since.

In 1836 I forwarded a paper, setting forth the above idea by an application of it to a number of vital phenomena, to the Professor of Anatomy in the University of Maryland, requesting him to advise me as to the best mode of bringing the subject to the notice of the medical profession. My communication was treated with contempt, as were also several papers written on the same subject, and shown to members of the medical profession.

Although I was fully convinced, from the period mentioned above, that the calibres of the tubes and hollow organs were increased by the action of their muscular fibres, I did not fully comprehend how this occurred until the spring of 1842. At that time, being in conversation with a gentleman who was fond of gesticulating, he, in derision of something that was said, thrust out his tongue over his under lip. This sudden elongation of the tongue instantly suggested that which I had been in search of for eight years—a rational explanation of the action of the fibres about the tubes. The truth flashed on my mind, *that the fibres of muscles are actively elongated by innervation.*

In 1843—February 24—I wrote an Essay on Muscular Action, embracing the idea just mentioned, applying it to the action of all the muscles in the animal body, and showing its application by a number of experiments on living domestic animals and on my own person. This essay is certified by me, under oath before a magistrate, as having been written at the time at which it bears date.

In 1844 I wrote another essay on the same subject, and illustrated my views by a reference to a large number of instances taken from natural history. This essay is included in the same pamphlet with the last, that was published in 1860.

In 1848 I published a small pamphlet, entitled "Outlines of a New System of Physiology," and at the same time a circular to be enclosed with it, referring to instances in natural history in corroboration of the correctness of my view of muscular action. This pamphlet and circular were gratuitously distributed the same year to all the most distinguished physiologists and physicians in Europe and in this country of whom I had any account.

In 1850, having carefully reflected on and retraced the mental process by which I had been enabled to arrive at and to apprehend the law of muscular action, I wrote and published an essay, entitled "An Account of the Reasoning Process," and instanced this process in the discovery of this law.

In 1852 was published my "Notes on Carpenter's Human Physiology;" and,

In 1857, the first forty pages of "Principles of General Physiology"—merely as a record of conclusions at which I had arrived, but which I had not time to arrange in any order.

In 1859—in May or June—my essay on the Law of Muscular Action was printed; and in 1862 "The Action of the Voluntary Muscles," embraced in the present essay.

Most of the above publications have been distributed freely and gratuitously, wherever it was thought probable they might awaken an interest.

GEORGETOWN HEIGHTS, *October*, 1865.

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By LOUIS MACKALL, M. D.

A LEADING object of science is "the endowment of man's estate" in nature, by the aiding of human Invention. This object is best attained by the exercise of human reason, in tracing out the true laws of nature, that are the real potentials, and the only proximate causes in natural phenomena. This essay is intended to set forth a law of nature relating to the movements of the muscles in the living body, that we have traced out, and that has hitherto been overlooked by Physiologists. A knowledge of this law must lead to a more intelligible and rational explanation of the animal functions, and at the same time will suggest more efficient and certain means of attaining ends in the practice of the medical Art.

In the investigation of the laws of nature, it is essential that the facts or phenomena from which we start, and which we make use of in our reasoning, should be taken from the particular department of science to which such laws will belong. When investigating the laws of nature that relate to physiology, is it not unphilosophical, to say the least, to reason from facts taken from the department of physics? This, however, is what is being done by Physiologists in their investigation of the subject before us. Their reasoning on this subject is, for the most part, confined to facts connected with electricity, which is a branch of physics; and, indeed, it is proposed as a most desirable object, *that we should have a* PHYSICAL THEORY *of physiology*.

The experiments that have been made with electricity,

with a view to elucidate the action of muscles, have served rather to retard than to advance the progress of physiological science, for the very plain reason, that the phenomena presented in these experiments were misunderstood and misconstrued.

Electricity cannot be substituted for the nerve fluid; it cannot be made to subserve the same purposes in the living economy. These two forms of matter are totally different in their natures. Electricity pertains to the earth and to inanimate matter, while the nerve fluid pertains to animants, or living beings. Electricians, as well as physiologists, have been in error in assuming that the *contraction* of the muscles was their *state of action*, and in supposing that when a current of electricity is passed through the living body a cause of action is *determined to* the muscles, when, in fact, the nerve fluid is *abstracted from* the nerves of the muscles.

When a strong current of electricity (as what is called a stroke of lightning) passes through, or near to, a living body, the nerve-fluid of the body, by virtue of a law of nature that we have elsewhere pointed out, *passes into and along with this Life-current;* and this fluid being lost to the body, death ensues; as happens to animals, trees, &c., that are struck with lightning. When a stronger or more concentrated current of electricity is produced by means of the large galvanic battery, all natural forms of matter may be decomposed by this current, and resolved into more simple forms, or into the most simple form—*the element of matter;* but when the current is more feeble, (as that from an electric machine, or from a voltaic pile,) and is made to pass through the body of a living or recently killed animal, a portion of the nerve-fluid is abstracted from the nerves of the muscles, to pass along with this feeble current, that is sufficient to induce their *state of contraction*, which is not their *state of action*, as will be presently explained.

We deem it proper to state fairly, at the outset, some of the conclusions at which we have arrived, in order that the reader may form some notion of the views we are about to offer to his consideration, and that he may thus be enabled the more readily to follow or apprehend our meaning as we proceed.

There are four separate states, or conditions of a muscle, in the living body. 1st, *its static condition*, or the state of rest or repose; 2d, *its state of action;* 3d, *its state of contraction;* and 4th, *its state of relaxation.*

In the first of the above states—the static condition—there

is a partial or moderate determination of the nerve-fluid to the fibres of the muscle, and there is also a moderate action or suction in its corresponding nerve-centre, withdrawing the nerve-fluid partially from the muscle, and thus giving it tone or a certain degree of tension. In the second state—the state of action—there is a full determination of the nerve-fluid to the fibres of the muscle, attended with *the erection and active elongation of these fibres*. In the third state, the state of contraction, *the action is in the nerve-centre of the muscle contracted;* the nerve-fluid is thus withdrawn from the fibres of the muscle, and its contraction thereby induced; and the fourth state, that of relaxation, is dependent on a want or absence of a proper action in the corresponding *nerve-centre;* when the nerve-fluid is suffered to flow passively, as it were, to the fibres, and thus to induce their partial elongation, and their loss of tone or atony.

That my views on this particular point may be fully understood, let me repeat: When a muscle is in its normal state of rest in the living animal body, there is a partial determination *to* it, and a partial withdrawal *from* it, of the nerve-fluid, so that it is always, to use a sporting phrase, "held well in hand." When the nerve-fluid is determined fully to a muscle, it is thrown into *a state of action*, and its fibres become *erected* and *actively elongated*. When this state passes off, the muscle returns to its *static condition* or state of rest. When a muscle is thrown into a state of contraction, it is in a very different condition from that of its state of action, for here the nerve-fluid is *withdrawn* from its fibres towards its corresponding *nerve-centre*. As the contraction ceases or passes off, the contracted muscle also returns to its static condition, and is at rest. When the fibres of a muscle are relaxed, or are in a state of relaxation, this proceeds from a *loss* of power or of action in the corresponding *nerve-centre*, arising either from exhaustion from previous inordinate action of the centre, or from some deleterious influence, as of a sedative, or of some virus, exerted either on the parenchyma of the centre, or the nerve-fluid, producing some change in its normal constitution. The peculiar state of the muscles in the animal recently deceased, called "*rigor mortis*," has a like origin with the state of relaxation, and should be referred to this state. When death occurs, there being no agency by which any part of the nerve-fluid can be retained in the nerve-centres, the *whole* of this fluid flows to the muscles, and superinduces the condition of the muscles spoken of, resembling in some

respects their state of action. As the nerve fluid evaporates or passes from the dead body, this condition of the muscles passes away.

The three following general conclusions will also be found of use in comprehending what we shall afterwards have to say on the subject before us:

1. When an impression is made, or an irritation produced on any point in the living body, such impression or irritation may be followed either by an action or *elongation* of the fibres at the point of irritation, caused by a determination of the nerve-fluid to such fibres; or, it may be followed by a *contraction* of the fibres of the part, induced by the *action* of the *centre* and the consequent withdrawal of the nerve fluid from such fibres—a number of circumstances, which it is not necessary to stop here to consider, determining which of these effects shall be produced.

2. Where there is a concatenation or a series of acts combined or linked together in one or more functions, if one of such series is brought into play, others of the same series take place until the whole series is performed. This is seen in suspended animation, as in drowning, when a mechanical movement of the chest will sometimes set in motion the series of acts constituting respiration, and also those of the circulation of the blood. The same thing is seen in retained placenta and in some cases of slow parturition, when the introduction of the hand will start a series of acts that result in the expulsion of the placenta or in the birth of the child.

3. There is a condition of the human body that is commonly referred to, among physicians, as *a state of nervous excitement*, but would be more properly called *a state of exalted action in the nerve-centres.* When an unusually strong or striking impression is made on the mind, whether physically or morally—that is to say, whether intermediately through the bodily organs or directly on the mind, the individual instinctively determines an extra quantity of nerve-fluid *to the centres*, and this fluid is accumulated there at the expense of the secretory and muscular systems of the body. All the emotions tend to produce this state of exalted action in the *nerve-centres*, and especially in the large centres, as the brain, the cerebro-spinal axis, the solar plexus, the semilunar ganglion, &c. The condition of the system to which this paragraph relates is one of the most important practical points in pathology, as it presents a remarkable instance of *the action of the nerve-centres*—a knowledge of which is in-

dispensable in gaining any clear view of vital functions, and especially of the movements of the muscles.

OF THE MOVEMENTS OF THE INVOLUNTARY MUSCLES.

The involuntary muscles are, for the most part, placed about the walls of the tubes or hollow organs of the body, and have their fibres arranged about these walls, some circularly or semi-circularly, others spirally, and others again longitudinally. After what we have said above of the conditions of the muscles in the living body, it will at once appear, that when these muscles are brought into a state of action, and have their individual fibres *erected and actively elongated*, they must tend *to expand*, *to dilate* or *to increase the calibers and the diameters* of the organs about which they are placed. And, again, when the same muscles are thrown into a state of *contraction*, and have their fibres shortened, that this state must tend *to reduce the calibers and diameters, and to obliterate the cavities* of such organs. These results we shall meet with in every instance of the movements of this class of muscles.

To enumerate some of the organs in which the involuntary muscles are placed, we may mention the dura-mater, with the neurilem or casing for the nerves; the primæ viæ, embracing the mouth, the esophagus, the stomach, and intestines; the lacteals, with the recaptaculum chyli and its ducts; the heart and blood-vessels; the gall-bladder, the urinary bladder, and their ducts or outlets; the uterus, with its appendages, &c. The walls of all these organs, having fibrous structures, are composed in part of the fibres of the involuntary muscles.

But, it will be asked, what facts have we to show that the action of these fibres tend to expand or dilate, rather than to contract or constrict, these organs? I answer, the facts of this character are to be found in almost every part of the animal kingdom. I will briefly refer to some of them.

In certain insects, as in wasps and bees, there is a fibrous coated bladder placed near the stomach, with a duct leading into or communicating with the esophagus. Both the anatomy and the function of this organ were very carefully and closely examined by G. R. Treviranns, a German naturalist.

Treviranns, in many vivisections, plainly and distinctly observed this organ or bladder to be gradually dilated or expanded at the will of the insect; and by thus inducing a

rarefaction of the air in the bladder, he saw these insects draw up fluids into and through their proboscis and esophagus until they entered the stomach. He called this viscus the sucking-stomach, because it served to suck up the fluids as stated.

The membraneous pouches that are appendages to the stomach and intestines of the leech are organs of the same structure and function as the sucking-stomach of insects, and to them is attributable the extraordinary power of suction possessed by these animals.

There are aquatic animals of a low order that are possesssed of bladders that they use as floats, and which are dilated or constricted at will, in order to rise or to sink in the water. These organs are beautifully represented in *Physalns* and in *Cuvieria carisochroma.* The anatomy and the functions of such bladders are the same with those of the sucking-stomach. They are fibrous, and are expanded for the purpose of causing a rarefaction of their contents.

The respiratory chamber or lung of the snail is a membraneous sac, that may be plainly seen to be gradually *expanded and collapsed* for the inspiration and expiration of air.

The lungs of the *cheloniæ* are membraneous sacs of the same character with the above, with like action; that is, they are expanded and contracted in calibre without aid from other organs of respiration, the chests of these animals being fixed, or immovable, and having no intercostal muscles.

I beg the reader to pause here, and to consider *well* the facts that we have now brought to his notice. If he does this, he will find that there is no conceivable explanation of these facts—that there is no mode that can possibly be imagined in which these fibrous-coated sacs could be expanded or dilated, as we have seen, *but by means of the erection and active elongation of the fibres about their walls.* When arrived at this conclusion, which is unavoidable, and observing that these organs are expanded when in an *active* condition, it is a fair conclusion, that the muscles, or their fibres, when thus *erected and actively elongated, are in their true state of action.* If this was the *state of action* of the muscles in the instances before us, it must be their *state of action* in all other instances. We need not stop here, but may proceed to the final conclusion, that there was *a law of nature* from the beginning, and that has been in operation from the dawn of the creation of the animal kingdom, *by virtue of which, when the nerve-fluid is determined to, or is present to a muscle, its fibres become erected and actively elongated.* We shall find the

evidences of the operation of this law of nature in every function of the animal body.

Without the use of this law of nature, the facts or phenomena mentioned, together with an innumerable host of others of the same character, must ever remain unexplained, or must continue, as heretofore, unsusceptible of any rational explanation. We proceed with the application of our views of muscular action, or of muscular movements, to some of the more important functions of the human body.

OF THE MUSCLES OF RESPIRATION.

The muscles of respiration in the human subject may be stated, in a general way, as being the abdominal muscles, the diaphragm, the intercostal muscles, and the fibres of the parenchyma of the lungs that are placed around the vesicles, or individual air cells.

In the fœtus these muscles are in their static condition, and the cavities of the chest and of the lungs are nearly obliterated, or have their walls nearly in contact. But at birth, or as soon as the air comes in contact with the lining membrane of the nares, or of the air passages, an impression is made that is immediately followed by a determination of the nerve-fluid to the muscles of respiration—and they are brought into their *state of action*. The erection and active elongation of the fibres of the abdominal muscles, the Recti, and Obliqui, would raise the anterior walls of the chest and remove them from the spine; *the action* of the fibres of the diaphragm and of the intercostal muscles would expand or dilate the chest, and at the same time the action of the vesicular fibres would dilate or expand the air vesicles of the lungs. The air would consequently flow into the space thus prepared for it, to perform the part assigned to it in this function.

When *the state of action* passes off from the muscles of respiration, they return to their *static condition*, and of course the cavities that were expanded by their action, have their calibers reduced and their contents expelled by the shortening of these fibres. This is a fair statement or account of ordinary respiration; but the contents of the lungs can be forcibly expelled, as in coughing or sneezing, &c., by the *withdrawal* of the nerve-fluid from the muscles of respiration, and thus throwing them into a state of *contraction*, from whence they are again restored to their *static condition*, and are ready to repeat the normal acts of respiration.

OF THE MUSCLES ABOUT THE WALLS OF THE PRIMÆ VIÆ, OR ALIMENTARY TUBE.

The action of the muscles or fibres about the alimentary tube, or what is called the peristaltic action, is misapprehended by physiologists. The contents of this tube are not *forced* along, as the term peristaltic implies, but are rather *drawn* along, as the air is drawn along into the lungs. The motion of these contents is referable rather to the principle of suction arising from the vacuum formed, *a fronte*, than to the principle of propulsion arising from the motion or cessation of action in the muscles engaged in this act.

The action of the alimentary tube, as it regards its extent or limits at any one time, has not been properly noticed or attended to. This may clearly be observed in the esophagus of animals that have long necks; as in cattle, horses, &c.; being exhibited in the appearance as of a ball passing down the esophagus when swallowing their food. The action spoken of, that is, the distension, or rather expansion, is here seen to be confined to a short extent, or to a limited portion of the tube, at any one time, and to pass regularly from one portion to another throughout the whole length of the esophagus.

To satisfy myself of the correctness of my views of this action, I made, many years since—I think in 1834—the following experiment: I exposed the esophagus of a game fowl by making an incision down the neck in front, and dissecting back the integuments. A grain of corn being placed within its bills, it was swallowed, and the action, such as I have described, was plainly observable. The grain was evidently nowhere pressed upon, or, in other words, there was no friction attending its passage; but it was seen to roll along rather, as has been said, by the force of suction than by that of propulsion. To show that the expansion mentioned was not dependent on the grain of corn or the contents of the tube, I induced an act of deglutition by irritating the fauces with a feather, when the same action as before, that is, the limited expansion, passed along the esophagus regularly from the fauces to the crop. To avoid all doubt on this latter point, I then placed around the esophagus, about its middle, two threads, at such distances from each other as would include the expanded portion. A single tie was now made on each thread around the esophagus, but left loose, so that the action of the organ might not be impeded; then, taking hold of the extremities of the two threads, and an act of deglutition being caused by an assistant, when the

dilatation reached the space included by the threads, the latter were quickly drawn tight, so as to detain the contents of the tube, had any been present. The dilatation immediately passed away from the included portion of the tube, as if no ligatures had been applied. Continuing the experiment, I induced deglutition by using a strong solution of tartarized antimony, when the course of the action became reversed, commencing at the crop and terminating at the fauces. I may here remark, that the contraction of the portion of the tube from which the action had passed was carried beyond the quiescent state of the organ, and then was immediately restored to that state. This limited action of the alimentary tube, which we have pointed out in the esophagus, occurs throughout its whole length; one portion of the stomach is first brought into action and then another portion, as is also the case in the duodenum and in the other intestines.

The true account, then, of the passage of its contents through the alimentary tube, as may be derived from what has been said, may be thus summarily stated: The food being prepared in the mouth by mastication, &c., is pressed against the palate and suggests the act of deglutition, which is performed by determining the nerve-fluid to the muscles of the pharynx, and thus causing its expansion, and forming a vacuum for the reception of the morsel of food presented. From the pharynx the action is transferred to the upper portion of the esophagus—*the normal action in the tubes always being at a point in advance of that where the impression is made*—and the morsel of food, formed into what is called a bolus by the passive contraction of the pharynx, is drawn along into this second step of its progress by the suction induced by its expansion. This transfer of action and consequent motion of the contents of the tube are repeated until, having undergone all the changes to which they are destined, and having subserved all the purposes required, these contents are finally rejected as fæces.

OF THE MUSCLES PLACED ABOUT THE WALLS OF THE HEART AND BLOOD VESSELS.

The impression made by the presence of the blood in the large veins near the entrance to the left auricle suggests the act of dilating this auricle for its further passage along its course. This is effected by innervating the pectimated muscles and other fibres placed about the walls of the auri-

cle, when the fibres of these muscles becoming *erected and actively elongated*, the required dilatation is provided, and the blood from the veins just mentioned flows into the vacuum thus formed.

Again, the impression of the blood in the left auricle suggests a similar act to be directed to the fibres around the left ventricle, and the flow of blood into this chamber of the heart takes place.

From a consideration of the position and attachments of the fibres of the columnæ carneæ and chordæ tendineæ, it will be understood that the tendency of the action or active elongation of these fibres is, *to raise the valves* to which they are attached, and thus to close the entrance or passage from the auricle to the ventricle. The active elongation of the fibres of the valves also contribute to the same end. I will take this occasion to say, that this view of the proper action of the valves, which is applicable to all the valves of the living body, does away with the absurd supposition that the regurgitation or reflow of the blood is essential to the closing of the passages about which the valves are placed, the elongation of their fibres being all that is required for this purpose.

The effect of the arrangement we have noticed of the valves of the heart is, *to measure off*, as it were, and to regulate the quantity of blood that is to pass along in the circulation at each pulsation or action of the organ. From the left ventricle the action is transferred to the fibres about the walls of the arteries of the general system, the dilatation of all of which is synchronous; and again from the arteries the action is transferred to the capillaries, and then to the veins, each of which systems of vessels having its own peculiar action, resulting altogether in the delivery of the circulating fluid at the entrance to the right auricle, whence it is carried through the lungs, or what is called the lesser circulation, through organs similar to, and on principles the same as those already spoken of.

OF THE MUSCLES ABOUT THE WALLS OF THE TUBES OF THE URINARY AND GENITAL ORGANS.

The action required for the transmission of the urine through its proper vessels or tubes is so evident from what we have already said, that the application here of our views will require but little detention.

The urine, when formed in the kidneys, is conveyed to

the urinary bladder by the alternate dilatation and contraction of the ureters, or by an action in these tubes similar to that we have minutely described as taking place in the esophagus. The action or expansion of the urinary bladder is proportioned to the quantity of urine brought to it by the ureters, until the limit of its expansion is reached, or until such impression is made by its presence as to suggest the transfer of the action to its sphincter and to the urethra; when the urine is expelled, being assisted in its flow by the contraction of the fibres of the fundus of the bladder. The last portion of the urine is forced out from the bladder and from the urethra by the action in its nerve-centre, causing a more perfect *contraction or constriction* of these organs.

The principal tube belonging to the genital organs in the male is the same with that of the urinary organs just mentioned, the urethra being used in common for the discharge both of the urine and of the semen. It is only necessary to observe here, that the latter being more highly animalized than the former, the action attending its discharge is more energetic than is that we have alluded to, and consequently is more defined and clearly marked. This explains the fact that the semen is discharged in jets, while the flow of the urine is more continuous.

In reference to the erection of the male organ of generation, it is only necessary to advert to the fact, that the parts concerned in this act—the corpora cavenosa and the corpus spongiosum—are composed of a fibrous structure, intermixed with nerves and blood vessels. The active elongation of the fibres adverted to, explains all the phenomena—the extension of the organ, and the expansion and consequent injection of its cavities or caverns.

I come now, in the last place, to one of the most interesting instances of the operation of the law of muscular action that I have proposed, and that is in the action of the fibres about the walls of the tubes of the female organs of generation. That the tendency of the action in these fibres is to *expand* or to *dilate* the organs alluded to, or that the state of action in these fibres is a *state of dilatation*, no one can deny that does not first stultify his mind with the belief that there is no action in these organs when in a state of excitement, as in the venereal orgasm, in the state of pregnancy, or in that of parturition; or, with the equally absurd belief, that there is more action exhibited in these organs when in a state of repose than when in the states of excitement just mentioned. Will any one deny the fact,

that in the venereal orgasm the vulva and vagina are *dilated or expanded;* or that, in the state of pregnancy, there is *a constant expansion* of the uterus, or enlargement of its cavity for the accommodation of the fœtus; or that in parturition there is a regular series of active expansions, alternating with passive contractions, throughout the whole extent of the genital tube? If these plain and evident facts are not denied, then it must be acknowledged that the state of dilatation, or, as it is very improperly termed, the state of relaxation, is the *state of action* of the fibres; and that the states of repose and of *contraction* are the states of inaction and of *the action* of *the nerve-centres.*

The proper function, then, of the female organs of generation is this: The impression made by the male semen, either in the vagina or at the os tincæ, suggests an action, energetic in proportion to the importance of this function in the female economy, consisting in an active dilatation, alternated with the contraction of the several portions of the genital tube, continued through the uterus and along the fallopian tube to its fimbriated extremities; which latter, being elongated, are made to embrace the ovaries. One or more of the ova being vivified by the influence of the semen brought to it by the action just described, again makes an impression which suggests an action the reverse of the other, as was seen in the reverse action of the esophagus, and the ovum is sucked along by this action and conducted to the uterus, where it remains deriving nourishment until it has completed its fœtal period.

During the advanced stages of pregnancy the several component tissues of the genital organs—the nervous, the fibrous, and the vascular—are seen to become largely developed, and are thus prepared for the performance of the series of extraordinary actions required of them in parturition, and which occur in the following order: The full-grown fœtus makes an impression on the mother that suggests first the withdrawal of the nerve-fluid from the fundus and body of the uterus, and its determination to the fibres of the neck and mouth of this viscus. In this way the lower portion of the uterus is actively expanded, and the superior portion is passively contracted, or more firmly contracted, by the action of the corresponding nerve-centre, and the fœtus is thus pressed down and advanced in its progress towards its birth. The next act in the series is the more complete dilatation of the os tincæ and a simultaneous expansion of the vagina, accompanied at the same time by the contraction of the preceding

portions of the genital tube from which the action has passed. By this second act the fœtus is still further advanced, and approaches the external organ, which all this while has remained comparatively closed or contracted. In the third and last act of this series the fibres of the external organ or vulva are innervated and become actively elongated, the opening is thus enlarged, and, by the propulsion arising from the contraction of the portions of the tube behind, the child is born.

OF THE ACTION OF THE NERVES AND NERVE-CENTRES.

From what we have said about the action of the involuntary muscles, or of the fibres about the walls of the tubes or hollow organs, my meaning, when speaking of the action of the afferent nerves and of the nerve-centres, will be readily apprehended. It will be admitted that these organs are tubular, as their office is commonly supposed to be the circulation of the nerve-fluid. The fibres about these organs, as those of the neurilem and of the dura mater, &c., having the same function to perform as those about the heart and blood-vessels, when brought into a state of action, would tend to dilate or expand such nerves and centres, and thus to produce the *suction or withdrawal* of the nerve-fluid from the muscles, of which we have so frequently spoken.

OF THE ACTION OR MOVEMENT OF THE VOLUNTARY MUSCLES.

For the better illustration of their action, it will be found convenient to separate the voluntary muscles into the four following classes, viz: 1st, such as are attached by one extremity only, having the rest of the muscle free to be extended or retracted at will; 2d, such as are attached at both extremities, but are capable only of the same motion as the former class, that of direct extension or retraction; 3d, such as are arranged circularly about the openings of the organs, and serve as sphincters; and 4th, such as are attached to the bones at both extremities, and act by making use of the bones as levers.

THE ACTION OF THE FIRST CLASS OF VOLUNTARY MUSCLES

That are attached by one extremity, and have the rest of the muscle free to be extended or retracted.

Of the action of this class, we will advert to that of the muscles of the tentacles, in the lower orders of animals;

and among the higher orders, to that of the muscles of the tongue, of the ciliary processes, and of the male organ of generation. Perhaps there is no other instance in nature in which is presented, so fairly and clearly, the true condition of a muscle when in a state of action, as in that of the action of the muscles of the organ last mentioned.

Physiologists, by a resort to sophistry, of which we shall speak again, have ignored the action of these muscles, which is the same with that of all other muscles; for the state of erection produced by the action of these muscles is common to all the muscles of the living body when in action. Every muscle when in action is in a state of vital erection; which term should be understood to express simply the active elongation of the fibres, with a due supply of blood and of nerve-fluid to maintain this state. In the human subject the true character of the organ of which we are speaking is masked, as it were, by the great development of the blood vessels and nerves with which it is supplied; but this is not the case in some other species of animals, as in the horse, the ox, the hog, and the sheep. In these the main body of the organ is composed of longitudinal muscular fibres that may be actively elongated to a length of from twelve to twenty inches. The view of muscular action heretofore presented may be repeated in connection with the instance before us.

The suggestive impressions appointed to precede the active state of this organ having been duly received, the anima determines the nerve-fluid in an extra supply to its fibres, through the sensory and motory nerves of this organ. In consequence, the proper longitudinal and other fibres of the organ become *actively elongated*, together with the fibres about the walls of the vessels and sinuses, in which there is an increased flow and accumulation of blood.

With this accumulation of blood there is established the special circulation of the nerve-fluid to this point. The supply of this fluid is thus further enlarged, and the action of all the fibres is exalted to its extreme limit. This latter state of the organ is expressed by the term "venereal orgasm."

In this representation of the action of muscles, there are three points to which we desire to direct attention. The first is, the propriety of regarding the organ in question as a muscle attached at one extremity by two heads to the ossa pubis and ischia. The second is, *the active elongation* of the proper fibres of this muscle; and the third is, the *stiffening*

or rigidity of the fibres when in action. The two latter points are particularly worthy of attention, as they occur in every instance of muscular action, and, what is very strange, have been entirely overlooked by physiologists.

The ciliary processes are the small muscles or bundles of muscular fibres that are attached by one extremity to the margin or verge of the opening into the eye, called the pupil, and are so arranged that by their extension the pupil is diminished, or the opening narrowed; and by their retraction the pupil is enlarged, or the opening widened. Light is appointed to be the appropriate suggestive impression to precede the action of these muscles. When the eye, in its normal condition in the living body, is withdrawn from the light, the mind, not having received this suggestive impression, does not call into action these muscles, and they are consequently retracted, and the pupil is enlarged; but when the eye is brought into the light and the impression is made, the mind determines the nerve-fluid to these muscles, and they become extended in proportion to the supply of this fluid. By their combined action the pupil is diminished or narrowed, so as to exclude such quantity of light as might be injurious to the optic nerve.

Here, again, we have a vital erection in the essential conditions—the active elongation, and apparently the stiffening of the fibres; and it is worthy of remark here, that in inflammation of these and the adjoining parts, as in iritis, there is established the special circulation of the nerve-fluid to these fibres, and they become persistently elongated, and the pupil continues to be narrowed even when the eye is withdrawn from the light.

The longitudinal muscular fibres of the tongue (with a view to the elucidation of the action of this organ) may all be regarded as one muscle, that is attached at one extremity, with the other parts free to be extended or retracted at will. The active elongation or extension of these fibres when innervated, or when in action, is manifest in our own persons, if we confine our attention to the fibres in question; but this active elongation of the tongue in some of the lower orders of animals is very remarkable. Every one is familiar with the protrusion and elongation of the tongue of some of the domestic animals, as the dog, the cow, &c. This action of the tongue of the serpent is deserving of particular notice. When the animal is aroused or excited, it erects its head and thrusts out of its mouth its forked tongue to the extent of several inches. The suddenness and

celerity of the motion of the organ forcibly reminds us of the appearance of a flash of lightning.

It is impossible, I believe, to suggest any rational explanation of this phenomenon, other than that of the innervation and consequent elongation of the fibres of the muscles that belong to this organ. The suddenness and celerity of the motion precludes all other agency but that of the nerve-fluid passing along the nerves, which alone resembles in its motion that of the electric fluid.

The action of the tongue of the frog or toad, when it seizes its prey, is similar to that of the serpent.

A notable action of this kind is presented in that of the tongue of the chameleon. To facilitate its description, this organ may be divided into four parts. First, the anterior bulbous portion, formed by the interweaving of cellular and muscular tissues—with the appearance of the end of the trunk of the elephant, it is furnished, like this, with a fleshy forceps at the extremity, with which the animal seizes its prey; second, the middle or interior portion, *composed entirely of cellular tissue, formed into a number of bands or hoops, having the intervals between them supplied with very loose and extensile meshes of this tissue*; third, the lingual bone, being a process from the centre of the os hyoides, arranged in the direction of the tongue, on which, when the tongue is retracted, the cellular bands and meshes of the second portion, and a part of the bulbous portion, which is hollowed out for this purpose, are stretched or drawn, like the finger of a glove drawn over the finger; and, fourth, two well developed muscles, having their fibres arranged longitudinally, and largely supplied with nerves and blood-vessels. These muscles arise from the cornua of the os hyoides, one from each, and being arranged one on each side of the tongue, or of the central cellular portion, are inserted in the bulbous extremity.

When in a state of repose, or when retracted within the mouth, the organ is from an inch to an inch and a half long; but when about to seize its prey, commonly an insect, the chameleon creeps to within seven or eight inches of the object, and then fixing its body and taking aim, as it were, suddenly, and with the celerity of lightning, thrusts forward its tongue, and seizes the insect with the fleshy forceps at its extremity. The food thus taken is then drawn into the mouth by the retraction of the organ.

If what we have suggested be admitted to be the true law of muscular action; if innervation, or the determination of

the nerve-fluid to a muscle, is attended with the active elongation of its fibres, there is no difficulty whatever in comprehending or in offering a rational explanation of the phenomenon before us. The animal, it will be understood, determines its nerve-fluid to the lingual muscles, and the tongue is extended to the distance mentioned simply by the *action* or *active elongation* of these muscles. The food is also drawn into the mouth by the retraction of the same muscles, caused by the withdrawal from them of this fluid.

But what explanation of this phenomenon can be given without the aid of this law? We will give the only one we have met with worthy of any notice, that of Mr. John Hunter, in his own words, taken from the "Illustrated Catalogue of the Hunterian Museum:"

"This length of the tongue, its extension and contraction, are very singular, and, if well understood, most probably very curious."

"The cause and mode of the contraction of its length are not uncommon. The elongation of the tongue in this animal is perhaps like nothing that we are acquainted with in an animal body."

"The apparatus for this purpose is a small rounded body, which passes from the apex of the os linguæ (glosso-hyal) to the bulbous part, and then through the centre of the bulb. The part between bone and bulb consists of two different substances, one a whitish substance, which is the firmest, and appears to be capable of keeping its form; the other is softer and more transparent. That part which passes through the bulb consists only of one substance, and appears to be a sheath for the reception of the os linguæ."

The reader will please recollect that the apparatus here described by Mr. Hunter is nothing more than the bands and meshes of *cellular tissue* of which we have spoken above. But let him proceed:

"The first of these (*i. e.*, the whitish, firmer substance) appears to be composed of rings, or something similar, placed obliquely in contrary directions, so as to appear to be two spirals crossing one another. Whether the other or softer substance (the cellular meshes, L. M.) has any distinction of fibres I could not observe, but I suspect it is muscular. If I am right in my conjecture of this structure, and of its disposition, it will be no difficult thing to show how it may be elongated; for if these rings are placed transverse, they may be brought so near to one another as to shorten the whole very considerably; and if they allow of

being placed almost longitudinally, they must, of course, lengthen it very considerably; and this position can easily be produced by muscles, which I take the pulpy substance to be."

"The contraction of the tongue is owing to a degree of elasticity, but this appears to be only in the cellular membrane, acting as an assistant to the muscular. The muscular contraction is owing to two muscles, one on each side of the tongue. Each arises from the os hyoides on the inside of the os linguæ, and passes along the side of the tongue to its bulbous part; but before it gets to the bulbous part it spreads itself all round."

"In the centre of each of these two muscles passes a considerable nerve to the bulbous part, and also two arteries. When the two muscles act, they draw the tongue back upon the os linguale, which, as it were, passes through the middle elongator, then through the centre of the bulb, till the whole tongue is retracted. Although this middle body is drawn upon the os linguæ, yet it does not appear to be a hollow, like a pipe. It rather appears to be filled with a very ductile cellular membrane, as in every part of the elongating division of the tongue, in order to allow of the great difference in the situation of parts with respect to one another." (Hunterian manuscript.)

The Ant-eater (myrmeco-phaga) furnishes a remarkable instance of the action of the muscles of this class. The tongue of this animal is composed of two distinct muscles having different origins, and a different disposition of fibres. To simplify the subject, we may say one of these muscles arises from the sternum, and passing along through the muscles on the anterior surface of the neck terminates at the tip of the tongue, its fibres all being arranged longitudinally; the other muscle arises from the os hyoides, passes around the former longitudinal muscle in close spirals, forming a sort of case or sheath for it, and terminates with it at the end of the tongue.

When quiescent or in a state of inaction, the tongue of the ant-eater is probably about six or eight inches long; but when thrust into the ant-hills to secure its prey, naturalists tell us, it is elongated or protruded to the extent of *seventeen or eighteen* inches.*

The object attained by this curious arrangement of the muscles, in accordance with our view of muscular action, is

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* Cuvier's Animal Kingdom, edited by Griffith, vol. iii. p. 300.

evidently the free and unimpeded extension of the longitudinal muscle to its full capacity, by preserving its fibres, nerves, and blood-vessels from external pressure while threading the narrow passages of the ant-hill through which it is forced. This object is fully accomplished by the action of the spiral muscle, which tends to dilate these passages, or, at least, to enlarge and keep open the space enclosed by it in which the longitudinal muscle acts.

In the absence of this view, physiologists have been forced to adopt the very absurd supposition that the tongue of the ant-eater is protruded by the *contraction* of its *spiral muscle*.

The Woodpecker, as is well known, feeds on the grubs that burrow into the limbs and bodies of trees. The burrows are first exposed by pecking through the bark with its strong, sharp bill; and then the long tongue, like a flexible probe, is thrust in, as the ant-eater's into the ant-hill, and the grub being harpooned, as it were, is dragged forth. To adapt the organ to the purposes mentioned, the anterior portion of the tongue—I refer more particularly to that of the species called the Flicker (picus aureatus)—is composed of a horny, spear-shaped, barbed point; from this point there arise two muscles, tendinous at each extremity, but with fleshy bellies or middles, their fibres longitudinal; these muscles pass around the base of the cranium, one on each side, and then rests with free extremities in a groove or closed passage formed between the skin and cranium, and extending over the middle of the head from behind forward until it reaches the base of the upper mandible. Besides these, two other muscles arise, one from the ramus of the lower mandible on each side, and pass around the longitudinal muscles, forming a sheath for them through their whole length. The arrangements of these muscles are strikingly similar to that of the muscles of the tongue of the ant-eater, and doubtless their functions are the same. When the longitudinal muscles are innervated and elongated, the upper bill, which is then applied to the tree, becomes the basis or point of resistance from which the tongue is projected into the burrows; the other or spiral muscles acting, as suggested when speaking of that of the ant-eater, to preserve the freedom of the motion of the former, by protecting from external pressure the blood-vessels and nerves with which they are largely supplied.

The notion suggested by some, that the tongue is jerked forward by the contraction of the last mentioned muscles, is

absurd; as the means suggested are clearly inadequate to the end proposed. The contraction of any portion of these muscles could not effect a motion of the tongue to the extent of one inch; but, if contracted, the portions anterior to their origins would draw the tongue back and counteract the effect of the contraction of the portions of these muscles that are posterior to their origins; so that no effect of the kind suggested could result from the contractions of these muscles. The tongue is thrust into the burrows probably to a distance of from five to eight inches, judging from the extensibility of the organ in the living or recently killed bird.

The longitudinal muscles of the tongue are commonly regarded as the cornua of the os hyoides; but I think it more rational to regard them as muscles (as their appearance clearly indicates) belonging to this class—attached at one extremity, with the rest of the organ free to be extended or retracted at will.

The "Aij-Aij" is an animal whose habitat is confined to Madagascar. It presents several points in its natural history closely resembling those of the woodpecker. Like this, it feeds on a grub that burrows in the bodies of trees in that island; and it exposes these burrows by tearing off the bark with its teeth. The animal then introduces a long flexible probe and pulls out the grub. This probe, however, is not the tongue, but one of the fingers of one of the fore paws, which is curiously adapted in its structure to this purpose. The anatomy of this organ is not generally known, but I presume, from the office it is said to perform, that it is similar to that of the tongues of the ant-eater and of the woodpecker, that we have just described. In its retracted state it may present the appearance of a "shrunken" or "atrophied" member, as is represented; but its muscles are, I doubt not, well developed, with large blood-vessels and nerves, and capable of an extensive action of elongation.

The tentacles of some of the lower orders of animals are so similar in structure, in their action, and in the purposes they subserve, to the tongues of the higher orders, that we are induced to regard them as their analogues. These organs are composed of muscles, with longitudinal fibres that are attached by one extremity around the outer margin of the mouth, and are extended or actively elongated for the purpose of collecting and of bringing into the mouth the food or prey that may be floating in the element these animals inhabit. When the animals are reposing or not feeding, these organs are retracted; but when engaged in taking

their food, the tentacles are innervated and actively elongated or extended. In some instances, as in the *physalus*, the *onychoteuthis*, &c., this extension is carried to a distance of six feet or more.* For a more minute account of the structure and office of these organs, I refer to the works on comparative anatomy and physiology. Our theory of muscular action offers to the intelligent student a number of suggestions that will be found of great use to him in his efforts to understand the more complicated structure and action of some of these organs.

THE ACTION OF THE SECOND CLASS OF VOLUNTARY MUSCLES,

That are attached at both extremities; but their action is that of extension and retraction simply.

For the plainest instances of this action, we must again have recourse to some of the inferior orders of animals. The land terrapin furnishes several instances of this character, in the protrusion of its head, in the opening of its valves, &c.

From that part of the interior of the carapax or top shell, that corresponds with the lumbar vertebræ, arise two large muscles, one on each side of the vertebræ. Each of these muscles has three distinct heads, or bundles of longitudinal fibres, the longest of which arises from the most posterior vertebræ, and, extending along on the side of the dorsal and cervical vertebræ, is inserted into the occiput; the other two bundles of fibres arise a little in advance of this, and are inserted into the two cervical vertebræ nearest the head. Any one, who understands this arrangement of the muscles, and who has become acquainted with our view of muscular action, will readily comprehend how the head of the terrapin is protruded, simply by the innervation and consequent *elongation* of these muscles; and he will as readily comprehend how the head, when protruded, can be *retracted* within the shell by the withdrawal of the nerve-fluid from these muscles. In order to protrude the head, the terrapin must first open its shells for this purpose. This it does by pushing down the anterior valve of the plastrum or bottom shell, by which the space between the shells is closed. To enable it to do this, it is provided with two muscles, arising one on each side of the anterior dorsal ver-

* General Structure of the Animal Kingdom, by T. Rymer Jones.

tebræ, which, passing down on either side of the neck, are inserted into the front edge of the anterior valve. By elongating these two muscles the valve is pushed down and the shells opened. The limbs of this animal are protruded and retracted by a similar arrangement of muscles, destined to this end.

The snail (helix nemoralis) presents some remarkable instances of the action of muscles that belong to this class. The soft parts of this animal consists mostly in a large bundle or mass of longitudinal muscular fibres, with which the several parts, as the head, the foot, &c., are protruded from the helix or turbinated shell—that is, by the *active extension* of these fibres.

The eyes of the snail may be observed, when the animal is in motion, at the extremities of two fleshy tubes, or horns, as they are more commonly called, projecting from the head. From the mass of longitudinal fibres two separate bundles or distinct muscles arise, and, passing through the visceral cavity and traversing the horns, are inserted, one around the base of each eye, at the extremities of these horns. When the snail is at rest, the ophthalmic muscles are retracted, the horns inverted, and the eyes are thus securely packed away in the visceral cavity; but when it is aroused, and protrudes its head and foot, it also determines its nerve-fluid to the ophthalmic muscles, and, by erecting and actively elongating them, pushes forth its eyes. The horns are tubes supplied with muscular fibres, placed spirally about the walls; and when the longitudinal muscles are extended, these fibres are also extended; and in this way the calibres of the horns are enlarged, and thus allows a free action of the internal muscles with their nerves and blood-vessels. It will be observed that there is a striking resemblance in the arrangement and action of the muscles in this instance to those in the instance formerly mentioned of the tongue of the ant-eater. The explanations given by physiologists of these two phenomena are the same, and both are equally absurd. They say the eye of the snail is everted by the contraction of the spiral muscle of the horn! The longitudinal muscle, they suppose, is intended and used solely for the purpose of retracting the eye!

We will advert to but one other instance of the action of the muscles of this class; it is to that of the muscles of the body of the leech. This animal is possessed of two fleshy discs, one at each extremity of the body, by means of which it attaches itself to the surface on which it crawls—the discs acting as cupping glasses, and taking a firm hold wherever applied.

The walls of the body of the leech are mainly composed of muscular fibres that are arranged in three distinct layers. The fibres of the outer layer are disposed circularly, those of the middle layers spirally; but the fibres of the internal layer are all arranged *longitudinally*. By means of the latter layer of fibres the progression of the leech is effected. When stationary, the discs are attached to a surface near each other; but when about to move forward, the leech first detaches the anterior disc, and then, extending its body by elongating the longitudinal muscles, it again attaches this disc to the surface on which it is crawling, or to some near object. When this anterior disc is fixed, the posterior one is detached and brought up by the retraction or contraction of the same muscles, to be attached again near the former. In this manner the leech moves from point to point in its progress, sometimes with considerable celerity. In the same manner the progression of all crawling animals, annelidans, serpents, &c., is effected. They first fix some part of the body, and from this point the body is extended by the elongation of the longitudinal muscles, when they again fix the forward portion of the body; and by contracting these same muscles, by withdrawing the nerve-fluid from them, they draw up their length from behind. But why do I say this of all *crawling* animals, when the same mode of progression is common to *all* animals? as will be explained further on.

ACTION OF THE THIRD CLASS OF VOLUNTARY MUSCLES.

By a reference to the several states of a muscle in the living body, as presented in the beginning of this essay, it will be seen that all the phenomena to be met with in the movements of the sphincter muscles are fully explained. In the closed state of the openings, or in their natural state when at rest, these muscles are in the static condition, or at rest; when the muscles are thrown into a state of action, the openings are actively dilated, as in defecation or the natural discharge of the contents of the rectum and urinary bladder; when thrown into a state of contraction by the action of their centres, the openings are constricted, or firmly closed, as in the pursing of the mouth, the determined shutting of the eyelids, in tenesmus, &c. When the sphincters are in a state of relaxation from a loss of action in the centres, induced by fear or other depressing emotions, by an opiate, or by exhaustion from previous excessive action of the centre, the openings are more or less freed, and the contents ot

the viscus, as of the rectum, of the urinary bladder, &c., pass out; as frequently happens in articulo mortis, or other relaxed states of the system.

The error that has prevailed in relation to the action of these muscles has arisen from the difficulty in distinguishing the consciousness that attends the innervation of the muscles from that that attends the withdrawal of the nerve-fluid from them. The early Physiologists mistook the one consciousness for the other; and this mistake has continued in the books to the present time. They supposed that innervation was attended with the active contraction of the muscles and the closing or shutting of the openings. The really active state of the muscles they called relaxation, and supposed it was the result of inaction, or of an absence of the cause of action.

The absurdity of former explanations of some of the above phenomena we have pointed out in passing; but there are, besides, explanations of others of these phenomena given in accordance with the old theory, equally absurd and unphilosophical, to which we have not adverted. The explanations to which we allude are founded in sophistry, and are clearly traceable to this source.

Finding it utterly impossible to furnish a rational explanation, with the received theory, of phenomena such as are presented in the protrusion of the tongue of the serpent, above referred to, the Sophist, to get around this difficulty, *invented a new term*, by which all the facts of the case are obscured, covered up, and ignored. The organs, the action of which he could not explain, were said to be composed of *erectile tissue.* He did not stop to demonstrate even to himself this particular tissue, which in reality has no existence, (for these organs, like all the other soft parts of the animal body, are possessed only of the cellular, the muscular, and the nervous tissues.) This was no part of *his* design—his sole object being accomplished by the invention of the *term* that would serve, as it has served, to deceive the unwary and unreflecting. It is thought by these to be a sufficient explanation of all such phenomena to say, that the organs concerned are composed of *erectile tissue*, and become *erected* when actively elongated.

The idea commonly attached to this state of these organs is, that they are injected with blood, and are in this way extended. The fallacy of this idea is easily shown, however, by calling to mind the facts that these organs are elongated before receiving their extra supply of blood; and that, in

many of these instances, the celerity of the motion of the organ, as in the case before us, entirely precludes this idea. The blood could not, by any possibility, be transmitted through the vessels with a velocity to correspond with the motion of the tongue of the serpent, as indicated above.

ACTION OF THE FOURTH CLASS OF VOLUNTARY MUSCLES,

That are attached at both extremities, but make use of the bones as levers.

It is more difficult to convey a just conception of the action of this than that of any other class of voluntary muscles; because the means employed to produce the results are, here, much more complicated. The bones of the limbs to which these muscles are attached, and which are made use of as levers,are provided with two distinct sets of muscles, one on each of the two surfaces towards their line of motion; and their motion is not produced by the action of either set of muscles exclusively, but is caused by forces exerted by both sets at the same time. I repeat, *the movement of the limbs of animals is not due exclusively to the action of either of the two sets of muscles with which they are supplied, but each movement is effected by the action or active elongation of one set, and by the contraction of the opposing sets.*

The instances we shall select, in order to illustrate the true action of this class of muscles, will be such as are plainest and most familiar; that is, those that are to be observed in the action of the muscles of the limbs, upper and lower, of the human subject.

The action of these muscles are so misunderstood by physiologists, and so misrepresented in the books, that the technical terms employed to designate them are calculated to mislead. I shall, therefore, discard these terms as much as possible from our present consideration, and substitute others. In doing this, let it be understood that those I propose are suggested only for a temporary use—to simplify the subject to the general reader, and to elucidate the principles involved. I hope, however, that some new terms for these muscles may be permanently adopted that will be more expressive of the true facts of the case than those now employed.

The muscles on the anterior surface of the humerus or bone of the upper arm, embracing the biceps and bruchialis anticus, we shall regard as one muscle, and call it, from its position, the humeralis anticus muscle; and that on the pos-

terior surface of this bone, the triceps, we shall designate as the humeralis posticus muscle.

The humeralis anticus muscle, then, arises from the shoulder blade, (scapula,) near the joint of the shoulder, and from the bone of the upper arm, and, passing along its anterior surface, is inserted into the upper portion of the bones of the fore-arm.

The humeralis posticus muscle arises also, in part, from the scapula, and in part from the humerus, and, passing along the posterior surface of this bone, is inserted into a process of one of the bones of the fore-arm, called the olecranon process, that projects behind the joint at the elbow.

When the whole arm is extended or straightened out from the flexed position, the mode in which this extension is effected by means of the muscles just mentioned, after what has been said above, is plain and palpable. In this movement, the anterior or humeralis anticus muscle is actively elongated by the determination to it of the nerve-fluid, and at the same time the posterior or humeralis posticus muscle is *contracted*, by having the nerve-fluid *withdrawn*. The motion, it will be observed, is produced by both muscles, the anterior and the posterior; but the former only is *in action*, or is influenced by the cause of action—the nerve-fluid; it is in a state of vital erection, while the latter is thrown into a peculiar condition, that of *contraction*, by the *abstraction* of the cause of action.

Both of these conditions, that of *active elongation* and that of *contraction*, in the opposing muscles, are *essential and indispensable in every movement of the limbs.*

The opposite movement of the arm, the flexing it at the elbow from the straight position, is produced by an opposite condition of the muscles engaged. In this movement, the posterior muscle is innervated and *actively elongated*, while the anterior muscle is *contracted.* This action of the posterior muscle is better shown, however, in the following instance:

The action of the muscles, by means of which the fingers are moved, will be best shown by regarding them as two muscles, one on each surface of the bones of the fore-arm, from which they arise. We will call them, for the present, the brachialis anticus and the brachialis posticus muscle, each term embracing the long muscles that go to the several phalanges of the fingers on its respective surface.

The anterior or brachialis anticus muscle arises from the bones of the fore-arm towards the elbow, on the inner surface, and extending along in front, passes with its long ten-

dons across the palm of the hand, to be inserted into the several bones of the phalanges of the fingers, on their inner surface.

The posterior or brachialis posticus muscle, in like manner, arises from the upper portion of the same bones, but from their outer surface, and passing along on this surface, and, with their tendons over the back of the hand, are inserted into the bones of the phalanges of the fingers, on their outer surface, extending along even to the extremities of these bones.

The great difficulty in realizing the true action and agency of the muscles we have just spoken of arises from the fact mentioned above, when speaking of the sphincters, namely, that few minds are capable of distinguishing the consciousness or the mental sensation that attends the determination of the nerve-fluid to a muscle, that causes its *action*, from the consciousness or sensation that attends the abstraction of this fluid, that causes the *contraction* of a muscle. To make this distinction, it requires a patient education and training of the mind, more especially in those who have given some attention to physiology, and who have their minds preoccupied with erroneous views of muscular action. This mental preparation, however, is what few or none have set about; but when this difficult task is accomplished, it will be observed, that—

In flexing the hand, as in forcibly shutting it, or in grasping any object firmly, a determination of the nerve-fluid is made to the *posterior* or *brachialis posticus muscle*, and its fibres becoming actively or forcibly elongated, tend to produce the movement indicated. At the same time the nerve-fluid is *withdrawn* from the anterior or brachialis anticus muscle, and its fibres becoming forcibly *contracted*, the act of shutting the hand, or of grasping, is perfected and completed.

The opposite states of these muscles, that is, the innervation and *extension* of the anterior, and the enervation and *contraction* of the posterior muscle, it is evident, would produce the contrary movement of the fingers—the extending or straightening them out.

If I have succeeded in explaining to the satisfaction of the reader the action and agency of the muscles engaged in effecting the movements of the upper extremities, there will be no difficulty whatever in his comprehending the action and agency of the other muscles of this class that are concerned in the various voluntary movements of the living body. In all such movements, we repeat, two sets of mus-

cles are concerned, whose action is opposed the one to the other; but the position established is the result of the agency, mainly, of the set that is *in a state of action*, although in some measure attributable to the *contraction of the opposing set.* Thus, in assuming and maintaining the erect position of the body, the muscles on the anterior surfaces of the lower extremities of the spinal column, and of the walls of the abdomen and thorax, are brought into *action*, and the result is accomplished principally by the agency of these muscles, but in some measure, also, by the *contraction* of those on the opposite surfaces.

Again: In locomotion of the biped, for example, it is true the hinder foot is brought up to the advanced position; and, again, the foot is raised to be carried forward, by the contraction of one set of muscles; but the progressive motion—the extending the leg and foot in advance, and the projecting forward of the whole body—is effected by the *action*, *the active elongation*, or extension of the other set.

The mode of progression, we have said, is the same in all animals. In all a portion of the body is advanced from a fixed point by the *action* or extension of certain muscles, and in all a portion of the body that is behind this point,is brought up by the *contraction* of certain muscles. In this respect the halting gait of the biped—that is to say, when, in walking, he keeps the same foot always in advance, bringing up the hinder foot to it, and then moving the front forward again—is the same with the natural gait of the leech; and, again, the leech would imitate the natural gait, or the continued progressive motion of the biped, if, instead of attaching its hinder disc in the rear of the front one, it could carry it along forward and attach it in an advanced position, and so continue its motion, carrying its discs alternately forward.

The arrangement of the muscles in the lower extremities is somewhat different from that in the upper. The extension of the leg in a line with the thigh is effected by the *action* of the muscles on the *posterior* surface of the femur, which we embrace in the term femoralis posticus, assisted by the movements of the muscles on the anterior surface of the same bone—the femoralis anticus—that is at the same time thrown into a *state of contraction:* and, again, the *action* of the tibialis anticus and of the anterior longus digitorum, on the anterior surface of the leg or tibia, both of which muscles we designate by the single term tibialis anticus, tends to extend or straighten out the foot on a line with

the leg, and the action of the latter muscle to flex the toes on the sole of the foot, being assisted in effecting these movements of the foot by the contraction of the opposing set, viz: the gastrocnemius, the soleus, and the posterior longus digitorum, which together we designate as the tibialis posticus. The reverse action and contraction of these two sets of muscles would, of course, be followed by the reverse or opposite movements of the foot and toes.

A curious circumstance, confirmatory of the correctness of this view of the action of the muscles of this region, is mentioned by Mr. John Hunter, who suffered from a fracture of the tendon of the gastrocnemius, called the tendo Achilles. When this fracture occurred, he experienced, he says, the greatest difficulty in raising the toes from the floor in walking across the room.

The instances of the action of the muscles we have now presented are so plain, and the explanations given of the phenomena attending such action are so simple, intelligible, and rational, that, it appears to me, they must produce in every well ordered, unsophisticated mind that considers them a full conviction of the truth of the law of muscular action that we have suggested.

I have experienced, however, much opposition to my views of muscular action ftom the medical profession; yet no valid or even serious objection has ever been raised by any member of the profession. This opposition seems to arise either from a want of sufficient attention to the subject to enable them to understand it, or else from a vague and unfounded apprehension of a radical change in the practice of the medical art to which they have been accustomed.

This apprehension is unfounded, because, when they have become well acquainted with my views, they will find that they are in perfect accordance with all successful practice in medicine, and are only opposed to the false theories of medical books, which all physicians of good common sense soon learn to disregard in their practice. It is a point of the greatest importance to medical men in gaining experience, as it is in gaining experience in all other arts or professions, to be able to reason from the facts constantly presented to their notice, and to find out general principles for themselves, which principles they are compelled to make use of in their practice in order to render it successful.

This reasoning is, for the most part, conducted unconsciously, and the results are not traced out and fully

impressed even on their own minds; but are fully implied in the practice of every successful physician. What we have done in the premises is, merely to have applied the scientific process of reasoning to the discovery of one of these results of unconscious reasoning. A few examples will serve to communicate my meaning.

When the experienced physician meets with a case of spasm, or a prematurely contracted state of the muscles, connected, as it always is, *with an exalted state of action of the nerve-centres*, he does not make use of means calculated to *withdraw* the nerve-fluid from the contracted muscle, in order *to remove the contraction* in the muscle, as the theory he had been taught from the books would lead him to do.

For if the action of the muscle consists in its *contraction*, or if the determination to it of the nerve-fluid is attended with *contraction*, then the remedy for this state of contraction or spasm would be the reduction and the revulsion from the muscle of the nerve-fluid. He does not attempt this, however, but, on the contrary, he throws aside the theory of the books, adopts the theory of muscular action that I have presented, and assiduously sets himself to work *to determine the nerve-fluid* TO *the muscle or muscles* by every means that he has at his disposal—*by friction*, *by epispastics*, *&c.*—knowing well from his experience that this is the only practicable mode of relieving this contracted state of the muscles. The presence of the nerve-fluid, that had previously been *withdrawn* by the action of the *nerve-centres*, restores the muscles to their normal state.

Again, where there is enlargement of the blood vessels, as in inflammation, he does not make use of means to contract or shorten the involuntary muscles about their walls by determining the nerve-fluid to them, as by the use of stimulating applications, &c., *as the old theory would require;* but he again gives up this theory, and adopts the theory I have presented, and reduces the determination of the nerve-fluid by antiphlogistic remedies; by directing the determination of this fluid to some other point in the system, or by expending it in the secretion of pus.

And so in all other instances, our views will be found to support and to rationalize all successful practice, and to point out the errors committed in unsuccessful practice. It will tend to sustain the true art of medicine founded on scientific principles, and to put down empiricism and charlatanry.

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